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PLASTICS IN ENGINEERING

by E. M. Elliot, A.M.I.P.E.

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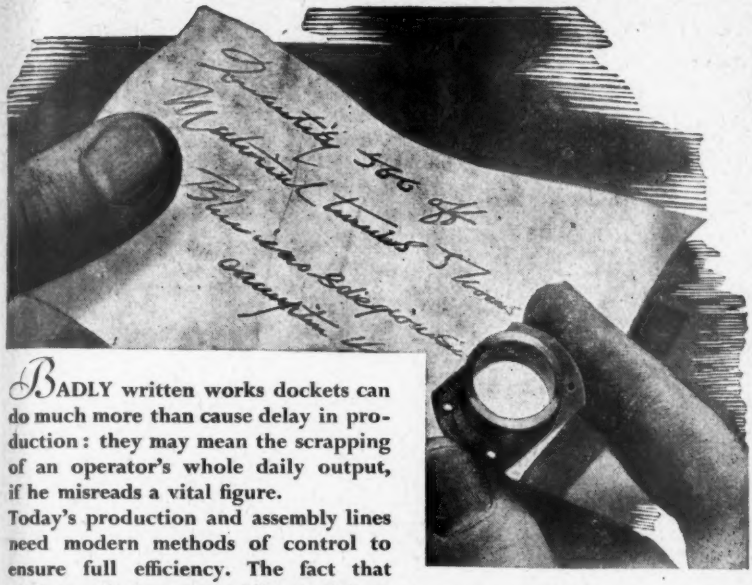

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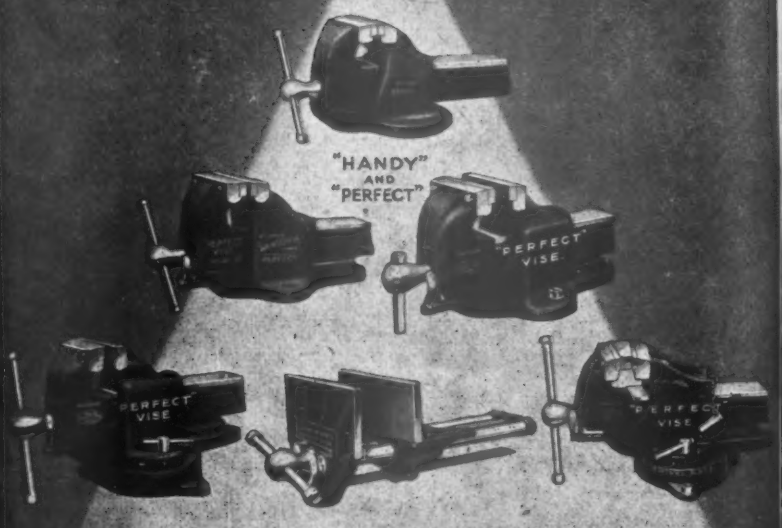

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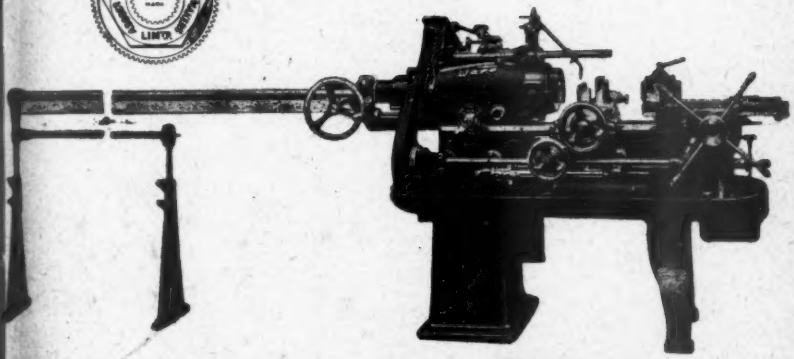

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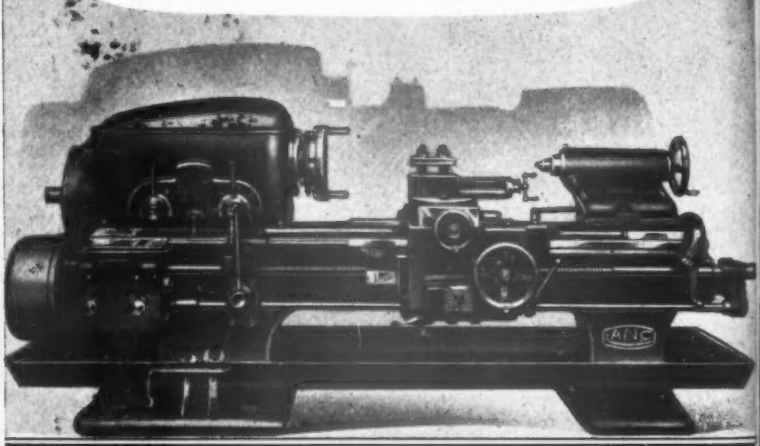

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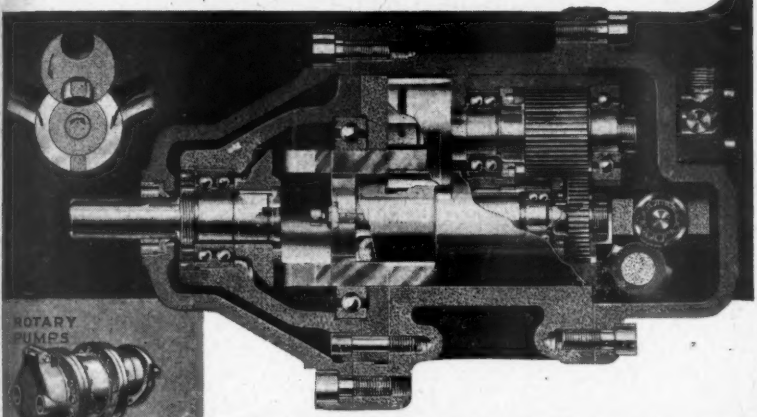

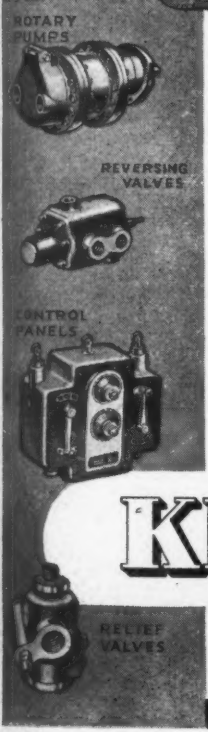

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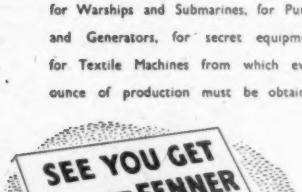

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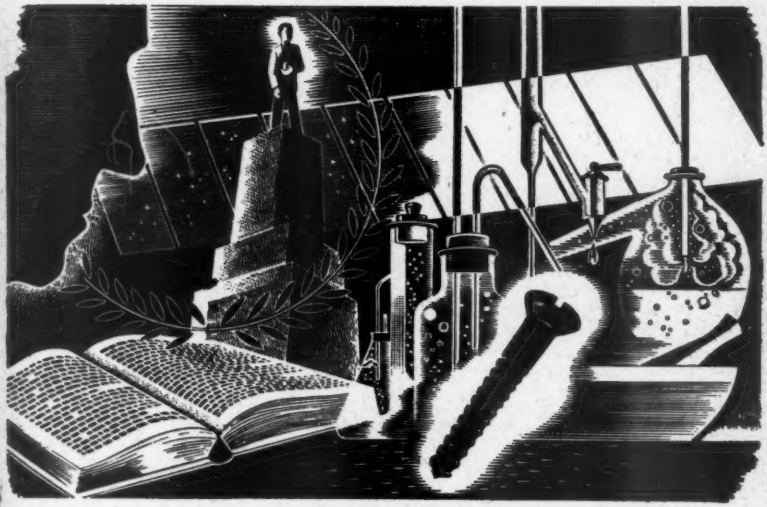

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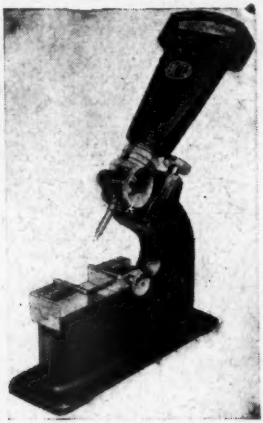

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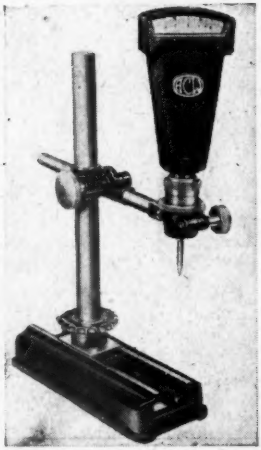

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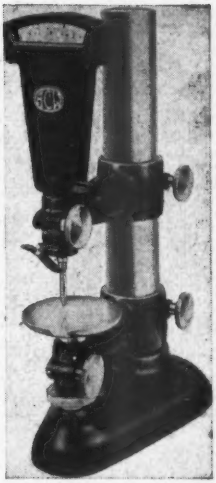

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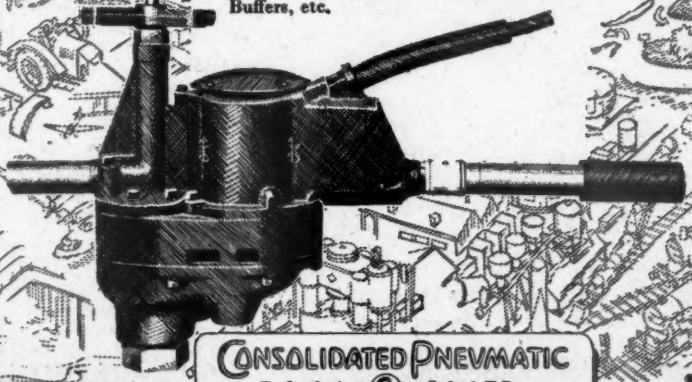

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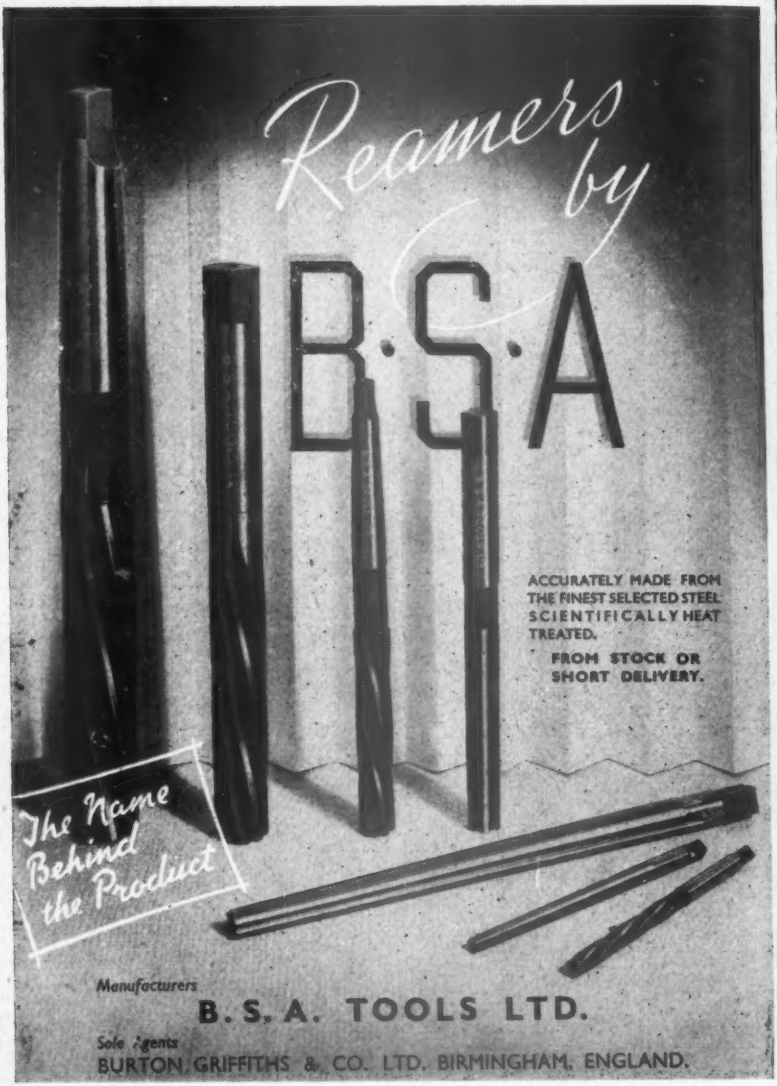
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PLASTICS IN ENGINEERING

Paper presented to the Institution, Glasgow Section, on 16th November, 1944 by E. M. Elliot, A.M.I.P.E.

Introduction

Plastic materials offer many attractive possibilities particularly from the point of view of the Production Engineer. This has been demonstrated by the co-operation which has existed between the manufacturers of plastic materials, designers, and production departments during the past few years.

Electrical engineers were among the first to make use of plastic materials and they have been quick to follow up and find applications for the newer plastics. To the engineering industry in general, however, plastics have been considered more as accessories, but now they are being recognised as suitable for a wide range of industrial, domestic, and decorative applications.

There has been considerable discussion about the suitability of the term "plastics" and many attempts have been made to give a definition. Perhaps the simplest is that included in a report "Post-War Building Studies—No. 3—Plastics" by a committee convened by the British Plastics Federation. The definition states "The term 'Plastics' is applied to a group of materials which, though stable at normal temperatures, are plastic at some stage in their manufacture and can be shaped by the application of heat and pressure."

Plastics have sometimes been thought of as "substitute" materials, and where used as such, have often proved to be more effective than the material originally used. The plastics industry stresses that plastics should be considered as alternative materials having certain properties by virtue of which they are capable of satisfying a particular set of conditions. This does not mean that plastics are suitable for all purposes or that a plastic material can always be used for a particular application.

Plastics, like all other materials have their limitations, and their applications must be controlled accordingly. Generally speaking, they are not suitable for use at sustained high temperatures. Some are unsuitable for applications where they are exposed to the weather whilst others tend to flow or creep under sustained loads.

The object of this paper is to discuss the properties of the plastic materials most generally in use today and to consider some of their applications and possibilities.

Historical

Bitumastic materials, familiarly known in the plastics industry as "muckite," are probably the first plastic materials to be used by the engineering industry and still have a wide range of applications. The introduction of celluloid about the middle of the last century could possibly be given as the birth of the plastics industry of to-day. Casein was discovered towards the end of the last century and cast phenol-formaldehyde at the beginning of the present century. Since that time there has come, in fairly rapid succession, cellulose acetate, phenol formaldehyde moulding powders and laminates, urea formaldehyde moulding powders, polystyrene, vinyl acetate, acrylic resins, vinyl chlorides, phenol formaldehyde extrusions, ethyl cellulose, nylon and polythene.

The chemical industry is experimenting with the development of these materials and the introduction of new plastics is to be expected. The engineer has, therefore, a very wide range of manufacturing plastic materials to consider and may expect more in the near future. In order that the right material is used in the right place, it is necessary to study the properties of these plastics.

Materials

It is not the purpose of this paper to discuss the chemical composition and build up of the different plastic materials. Many books have been written on the subject, but to the engineer they are perhaps mainly of academic interest. Dr. Caress, in a paper "Plastics and Engineering" read to the North East Coast Engineers and Shipbuilders, discusses the molecular structure of plastic materials and shows how the chemist can predict the general behaviour of a plastic material from a knowledge of the molecular construction, weight and distribution. The paper demonstrates the necessity for close co-operation between the chemist and the engineer.

Dr. S. Livingstone Smith in a paper "A Survey of Plastics from the Viewpoint of the Mechanical Engineer" presented to the Institution of Mechanical Engineers surveys the chemical composition of thermosetting materials with special reference to laminates.

A third paper of interest to the engineer is by Dr. P. D. Ritchie and was read to the Institution of Production Engineers under the title of "The Physical and Chemical Nature of Plastics and their General Classification."

These papers are mentioned in passing as being of interest to the engineer who does not have time, or want to read more weighty works on the chemistry of plastics.

Plastic materials can be divided into two main classes :

(1) Thermosetting, and
(2) Thermoplastic

Thermosetting Materials

Thermosetting plastics are those which, as their name indicates, solidify into an insoluble, infusible condition under the application of heat and pressure, and which cannot be further re-formed by the application of greater heat or pressure.

Thermoplastic materials are those which soften under the application of heat, becoming solid again on cooling. These materials may be softened indefinitely provided that the heat applied does not cause decomposition.

Whilst both thermosetting and thermoplastic materials are used for engineering purposes, it is probably true to say that thermosetting materials are in more general demand at the present time, excluding the cable industry, but with the introduction and development of new thermoplastics it is possible that the demand for these compounds will be very considerably increased.

The thermosetting compounds in general use at the present time are (1) phenol formaldehyde and (2) urea formaldehyde. Melamine formaldehyde is in use in America and it is anticipated that it will shortly be available in this country.

Thermosetting plastics are available in liquid or film forms for impregnation and bonding purposes and in powder form for moulding. The resins are very brittle and, therefore, of little use for engineering applications. The mechanical properties are improved by the addition of fillers, typical of which are wood-flour, cotton, fabric, mica, and asbestos. The properties of the final finished moulding are, in fact, to a large degree dependent on the filler used.

Phenolic Moulding Powders

B.S.S. No. 771 classifies phenolic mouldings in five groups:

G = general type
GX = improved type
MS = medium shock resistant
HS = high shock resistant
and HR = heat resistant

It is also possible to obtain powders developed for special applications such as low loss electrical or water resisting, etc.

The Supply Ministries have also drawn up specifications for moulding materials, and the finished components made from these materials. It is therefore, evident that plenty of data is available concerning phenolic moulding powders and mouldings.

The general and improved types of powders mentioned above are wood filled compounds and are used where a clean, sharp finish and reasonable mechanical and electrical properties are required,

For medium shock resistant compounds, cotton flock is used as the filling medium, whilst for the high shock resistant materials, chopped or shredded fabric or long fibre cotton materials are used as fillers. These compounds are used for applications where mouldings are required having greater impact strength than can be obtained with wood filled powders. The moisture absorption properties of cotton and fabric filled powders are inferior to those of the wood filled powders and, therefore, the electrical properties are slightly poorer.

Asbestos and other mineral fillers are used for the heat resistant class of phenolics. These powders are also used for applications involving chemical resistance.

In order to obtain good electrical properties at normal frequencies, wood filled powders are specially manufactured with a very low moisture content. Mica filled powders are used for high grade electrical requirements.

A general summary of the properties of phenolic moulding compounds shows the following :

Specific gravity : 1.35 to 1.40 except for mineral filled which are about 1.66 to 1.70.

Impact strength : wood filled 0.15 to 0.20 ft. lbs.
medium shock 0.30 to 0.35 ft. lbs.
high shock 1.0 to 3.2 ft. lbs. according to the filler used.

Tensile strength : 5,500 to 8.000 lbs/sq. in.

Ultimate crushing strength : 25,000 to 36,000 lbs/sq. in.

Cross breaking strength : 8,000 to 12,000 lbs/sq. in.

Young's Modulus in bend : $6\text{-}10 \times 10^5$ lbs/sq. in.

The electrical properties vary very considerably according to the filler used and whether the powders are high dielectric type or normal type. For example, the power factor at 20°C and 800 cycles per second for G and GX type powders ranges from 0.1 to 0.3 whilst for high dielectric powders, the value is 0.03 to 0.05. Dielectric strength ranges from 200 to 350 volts per mil at 20°C, but drops to 40 to 100 volts per mil for G type powders at 90°C. High dielectric powders have a dielectric strength of 100 to 150 volts per mil at 90°C.

Urea Formaldehyde Moulding Powders.

One of the limitations of phenolic moulding powders is the impossibility of producing them in light fast pastel colours. The resin produced by reacting urea and formaldehyde together is transparent and can be dyed or pigmented so that delicate pastel shades can be produced. The resin is filled with either paper or wood-flour,

the paper filled powders giving translucent mouldings, whilst wood filled powders produce opaque mouldings. Both paper and wood filled powders are free from taste and smell and resist electrical tracking.

Urea formaldehyde mouldings have a water absorption figure of 0.8% to 1.4% against 0.3 to 0.4% for a wood filled phenolic moulding. This high water absorption figure makes the material unsuitable for use where dimensional stability is required. The impact strength is 0.15 to 0.24 ft. lbs. and tensile strength 7,000 to 10,000 lbs/sq. in. The electrical properties at room temperature are of the same order as those of wood filled phenolic, but they decrease more rapidly with rise in temperature.

Melamine Formaldehyde.

This compound is one of the newer plastic materials, and whilst it is being used in America, is not readily available at the moment in this country. Melamine compounds are said to combine the more desirable properties of urea and phenolic moulding compounds. The colour range and fast moulding cycles of urea are combined with the superior water resistance of the phenolics. Melamine formaldehyde mouldings are however more brittle than u.f. or p.f. For uses in electrical equipment it is said that melamine materials combine the arc resistance of ureas with the heat resistances and dielectric properties of mineral filled phenolics. There is but little doubt that melamine powders will have a wide field of applications as soon as they become available.

Laminates.

In addition to the manufacture of phenolic and urea powders, phenolic and urea resins are used for impregnating and bonding paper, fabric and wood. The resultant materials have excellent mechanical and electrical properties and find numerous applications in engineering.

We are all familiar with paper and fabric resin bonded sheet sold under numerous trade names. These materials are made by impregnating the laminae with resin and pressing into sheets between heated platens. We are also familiar with plywood bonded with resin and made in the same way. Considerable advances have been made in bonding wood veneers, and materials known under the general term " improved wood " having high densities and mechanical properties are being produced. The manufacture of improved wood is a highly specialised process and close control must be exercised if the maximum results are to be obtained.

Improved wood may be manufactured by either impregnating the veneers with the synthetic resin, and after drying, assembling and pressing the veneers under heat, or alternatively, assembling

the veneers with a glue-film interposed between each one and again applying heat and pressure. The boards thus made are cooled to round about room temperature with the pressure maintained whilst cooling takes place. This is done to prevent distortion due to uneven cooling.

Pressures used vary considerably according to the density of the product and may be from 200 lbs/sq. in. to 8,000 lbs/sq. in.

Temperatures used are around the 150°C mark. The time required to press and cool depends on the thickness of the board required.

Synthetic resin adhesives are also available for different processing conditions and types of bond. The glues are based on aqueous thermosetting resins prepared by the partial condensation of urea or phenolic materials with formaldehyde. The action of gluing is to bring the chemical reaction of the resin to completion by adding a specified amount of hardening agent, by heating the resin, or by a combination of both methods. The resin sets to a hard, infusible solid, resistant to water and many chemicals, and so forms a strong durable joint between the glued surfaces.

A convenient method of using the cold pressing technique is to apply a thin, even coating of glue to one face of the joint and a cold hardener to the other face. The two faces are then brought together and pressed at around room temperature. The time of pressing depends on the resin and hardener used and also the temperature. The time will vary from around 25 hours at 10°C (50°F) to 1½ hours at the same temperature according to the hardening agent used. These times may be reduced to 45 mins. and 20 mins. respectively if the temperature is raised to 32°C (90°F.) At the end of the required period, the joint will have attained its maximum strength and may be used immediately after the removal from the press.

A further use for impregnated laminae which has been introduced comparatively recently and which is being developed by the moulding industry is known as "tailored moulding." This consists of blanking to shape impregnated paper or fabric in which the resin has been carried to the B stage, that is, the resin is partially cured. The blanks are built up into packs and placed in heated moulds and pressed. The resultant mouldings have extremely good mechanical and electrical properties and have a good finish, and can be produced to reasonably close tolerances.

Summary of Thermosetting Materials.

A summary of the thermosetting products available to the engineer for a wide range of applications shows that mouldings having reasonable mechanical and very good electrical properties may be

obtained from phenolic or urea, and in the near future, melamine formaldehyde moulding powders.

Phenolic and urea resins may be applied in a variety of methods to supply laminated boards of paper, fabric or wood. These boards have excellent mechanical and electrical properties and may be produced in varying densities according to the particular application under consideration.

In addition to these materials, mention must be made of cast phenolics and casein, but owing to their relatively poor properties, they are but little used by the engineering industry.

Thermoplastic Compounds

The range of thermoplastic compounds available is very extensive and in order to ensure the best material being used for any particular application, it is highly desirable for the designer to co-operate with the material manufacturer.

The best known thermoplastics in this country are the cellulose esters, acrylics, styrene, vinyls, polythene and latterly, nylon.

In the cellulose ester group, cellulose acetate and nitrate probably the most commonly used compounds. This was first introduced as a lacquer and later manufactured in sheet form, the moulding powder development coming later still. Articles made in cellulose acetate possess good electrical and fair mechanical properties as well as reasonable chemical resistance, and can be obtained in a range of colours. Those made from the nitrate suffer from a high degree of inflammability.

Cellulose aceto-butyrate has a lower water absorption figure than cellulose acetate and, therefore, has greater dimensional stability. It also has a higher impact strength but its tensile strength is a little lower.

The most common acrylic resin is polymethyl methacrylate. It is available in cast sheet, cast rod, or powder form suitable for compression or injection moulding. In addition to good mechanical and electrical properties, the material has excellent optical properties Methyl methacrylate does not melt in the accepted sense of the word, but softens between 70 and 110°C according to the amount of plasticiser it contains. It is far less fragile than glass, can be readily fabricated and is light in weight, the specific gravity being 1.19. Polymethyl methacrylate articles take a very high finish and do not easily craze.

Polystyrene moulding materials are particularly suitable for the injection moulding technique, and owing to its chemical stability, fastness to light, excellent electrical properties, and high water resistance, many and varied applications have been found for its use. It crazes more readily than polymethyl methacrylate, and is also more brittle.

Rapid advances have been made in recent years in vinyl plastics, among which the most important are polyvinyl chloride and polyvinyl acetate.

Polyvinyl acetate has a fairly low water absorption, good electrical properties and chemical resistance.

Polyvinyl chloride has a low water absorption, is odourless and and tasteless, and has good abrasion and chemical resistance properties. This material can be obtained having a soft rubber texture or may be rigid according to the plasticiser used.

Interpolymers of polyvinyl chloride and polyvinyl acetate combine the qualities of both the chloride and acetate materials. They are tough, have good water and chemical resistance, and are non-inflammable.

Polythene is a general term for a range of solid polymers of ethylene and is prepared by subjecting ethylene to high pressures under carefully controlled conditions. Polythene possess great water resistance and special electrical properties, such as very low power factor, (less than 0.0001 at 50 c.p.s. and 20°C and between 0.0002-0.00035 at 2×10^7 c.p.s. and 20°C); low dielectric constant (2.3 at 20°C falling to about 2.15 at 100°C at cycles ranging from 50 to 10^8 c.p.s.); high resistivity and dielectric strength, the break down voltage being in the region of 1000 volts per mil. measured on a specimen 0.02 in. thick in accordance with conditions given in B.S.S. 771.

The material has certain good mechanical properties. It remains tough and flexible at very low temperatures (−40°C). It is a typical thermoplastic and, therefore, its tensile strength, like that of all other substances in this class, falls with increasing temperature. The yield point is reached at about 90°C and it melts rather sharply at around 115°C to give a very viscous fluid.

This useful combination of electrical and mechanical properties makes polythene an excellent material for use in the manufacture of cables and accessories, especially those for high-frequency and high voltage work. Its resistance to water and to chemical attack also makes it a suitable material for many other uses where these properties are required, such as chemical plant.

Polythene is relatively easy to process as it is a thermoplastic which can be extruded and moulded by compression or injection. It can be easily machined without the use of special tools and can also be welded.

On stretching, polythene behaves like other crystalline plastics and exhibits the phenomenon of cold drawing. When the tension reaches a certain value, an irreversible extension takes place up to about 400% elongation. This is followed by a further slight rise in extension before the specimen breaks. Cold drawing of poly-

thene results in a marked increase in the tensile strength up to values of about 15,000 lbs/sq.in. Polythene may be obtained in granule form for moulding, also in sheet, rod, tube and film.

Nylon is the generic name given to all synthetic fibre-forming polyamides. In their chemical structure the nylons resemble products such as silk, hair and gut, but are, however, entirely synthetic in character. Owing to the large number of possible raw materials, many different forms of nylon can be prepared, with a wide variety of physical and chemical properties. Only a limited number of nylons are as yet available. X-ray measurements show that nylon is made up of long-chain molecules which enable it to be extruded into filaments and accounts for its great tenacity and toughness. To form a filament nylon is melted and forced through a small aperture into water where it solidifies. At this stage, the filament lacks its full strength and elasticity. A further step, in which the filament is cold-drawn to about four times its original length is necessary. This orientates the molecules, setting up an attraction between the chain and so considerably increases the strength of the filament.

Although still under development, nylon is a promising moulding material for special applications where toughness, chemical resistance and high softening point are required. For this application nylon in the form of small chips is used. Moulding equipment, preferably in stainless steel, capable or working up to 320°C is required. A high melt rate and rapid injection cycle are necessary.

The molecules in a sample of moulded nylon will not have been orientated and the physical properties of the moulding will, therefore, differ from those of orientated or drawn nylon. In their chemical resistance, density and water absorption both drawn and moulded nylon are similar. The chief differences are in the mechanical properties which for moulded nylon are : tensile strength 5,000-8,500 lbs/sq.in., elongation at break 30-35%, cross breaking strength, 10,000-15000 lbs/sq.in. The tensile strength of cold drawn nylon varies from 50,000-120,000 lbs/sq.in. according to the method and extent of drawing.

Summary of Range of Properties

A general summary of the range covered by typical properties of the more familiar plastic materials indicates the stage reached at the present time and is given by Dr. Caress as follows :

Density.

Densities range from about 0.95 (polythene) to 1.7 (polyvinylidene chloride). Much lower densities are obtained, of course, by foaming the resins and higher densities by the use of heavy mineral fillers. Cf. glass about 2.5, aluminium 2.7, steel 7.8.

Tensile Strength.

Range is from 2000 lbs/sq.in. for polythene, 4000 upwards for cellulose derivatives, 6000 for polystyrene, 9000 for polymethyl methacrylate to 20,000 for rolled nylon sheet. The tensile strength of thermosetting plastics depends on the filler, e.g., unfilled phenol formaldehyde 6000-9000, cellulose filled phenol formaldehyde and urea formalcehyde mouldings 8000-9000, phenol formaldehyde laminates up to 30,000 and special fibre reinforced phenol formaldehyde up to 60,000. Cf. duralumin 60,000, and steel about 200,000 lbs/sq.in.

The effect of cold drawing is most marked. Poltyhene increases to 5000-14,000 whilst nylon increases to 50,000-120,000 depending on the method and extent of drawing.

Ultimate Fibre Strength in Bend.

Tne trend of tensile strength is naturally followed by the bend strength, which, however, is higher in plastics, e.g., 5000 lbs/sq.in. upwards for cellulose derivatives, 7000 for polystrene, 14,000 for polymethyl lethacrylate, 10,000-12,000 for filled phenol formaldehyde and urea formaldehyde mouldings with laminates correspondingly higher.

Compressive Strength.

The range for thermoplastics is 10,000-15,000 lbs/sq.in. thermosetting plastics are higher, e.g., mouldings and fibre-reinforced producrs have compressive strengths up to 35,000 lbs/sq. in. approaching that of duralumin.

Young's Modulus.

Unfilled plastics do not approach metals in elastic modulus. The normal range for thermoplastics is 2×10^5 to 5×10^5 lbs/sq.in. with cellulose derivatives down to 1×10^5. The thermosetting plastics have higher moduli, 7×10^5 to 10^6 for unfilled phenol formaldehyde going up to 7×10^6 for fibre reinforced p.f. Cf. duralumin 10^7 and steel 3×10^7 lbs/sq.in.

Impact Strength.

Plastics are generally brittle compared with metals and thermosetting plastics do not compare too favourably with thermoplastics unless they are fibre reinforced. Published figures are not always reliable because the method of test is not always stated. The probable order, in increasing impact strength is unfilled phenol formaldehyde and cellulose filled phenol formaldehyde and urea formaldehyde mouldings, polystyrene, polymethl methacrylate, cellulose derivatives, polythene, fibre filled phenol formaldehyde and cold drawn nylon.

Hardness.

With a 2½ m/m ball and a 25 kg. load, Brinell hardness figures range from 20 to 50 (phenol formaldehyde) with nylon considerably harder. Cellulose derivatives and polythene are below 20.

The abrasion resistance of typical transparent plastics is indicated by the following relative figures : polystyrene 12, " Perspex " (plasticised polymethyl methacrylate) 18, cellulose nitrate and acetate 22, polymethyl methacrylate 30, glass 130.

Thermal Properties.

Conductivities range from 10^{-4} to 10^{-3} c.g.s. units. Specific heats are between 0.25 and 0.5 per °C. Linear expansion coefficients per °C are between 1.6×10^{-5} and 1.6×10^{-4}, generally higher than metals.

Useful Temperature Range.

Most plastics can be used at temperatures down to at least —40°C. Thermoplastics weaken with rising temperatures, the upper limit for continuous service being around 60°C and for some plasticised compositions even lower. Nylon with a sharp melting point of 264°C can be used up to temperatures approaching 150°C (unstressed —125°C loaded) but oxidation becomes a limiting factor at high temperatures.

Thermosetting plastics are less affected by heat, urea formaldehyde mouldings being serviceable at 70°C and phenol formaldehyde mouldings, having a cellulose filler, at 140°C. Phenol formaldehyde heat resistant filled mouldings may be used up to 180°C.

Fatigue.

Thermosetting plastics subjected to repeated stresses below their elastic limit will eventually fail at their weakest places. In general, the fatigue limit may be assumed to be 30% below the static test value. Thermoplastics, by reason of creep and cold flow, will deform to relieve internal stresses that may be present due to conditions of application. It therefore follows that the fatigue limit of thermoplastics may extend beyond that for thermosetting compounds.

Creep and Cold Flow.

Delmonte states " When an organic plastic is stressed there follows a true elastic deformation, followed in turn by a plastic deformation. There are two stages to the plastic deformation. The first is a change of deformation rate with time, known as creep and the second is a constant rate of deformation known as flow." These phenomena are of particular interest to design engineers as they indicate that plastics are susceptible to dimensional changes

and changes in unit stress when loads are applied for various periods of time.

Manufacturing Processes for Plastic Articles

Before considering some of the applications of plastic materials, a note on production methods may be of interest.

Moulding.

Compression moulding of thermosetting powders is such a well known process that it is not necessary to describe it. Transfer moulding is used for producing more complicated parts, and pieces having delicate inserts. For this operation, the mould is arranged in such a manner that the die cavity is closed and the powder loaded into a pot having a positively fitting plunger. Upon the application of heat and pressure, the powder fluxes and is injected into the die cavity through a gate connecting the powder well to the die cavity.

Thermosetting moulding powders may also be extruded as rods, tubes or sections. This is done on a machine in which the ram first presses the powder into a pre-heating chamber. The following charge of powder pushes the previous charge forward to the curing chamber which is heated in such a manner that the temperature gradient from feed end to orifice is such that the material is fully cured when it is extruded through the die. The feed is automatic and the process continues.

As previously mentioned the "tailored" moulding of components from shaped laminae of impregnated paper or fabric is becoming of increasing importance.

A method of producing large mouldings recently developed in the U.S.A. consists of thoroughly impregnating cellulose flock with a thermosetting resin. The impregnated flock is sucked on to a perforated metal sheet shaped to the form of the finished article. The pre-form thus made is then placed in a normal mould and finished by normal compression methods. This method ensures an even distribution of material over the whole surface of the mould and flow is reduced to a minimum.

The pressing of paper, fabric, or wood laminae into boards has already been described, but a note on shaped laminations may be of interest. This is accomplished by preparing the impregnated laminae to the required shape and building up packs which are laid against a former, covered with a flexible material such as rubber sheet, and subjected to heat and air or liquid pressure in an autoclave. By this method, larger parts can be produced than be the "tailored moulding" technique.

Thermoplastic moulding powders may be compression moulded, but this is usually a slow process involving heating the material

in the die under a light load and applying pressure when the material has fluxed. The die is then cooled, pressure being maintained while cooling in order to feed the contraction and avoid distortion. The more usual and most economic method of moulding thermoplastic powders is by the well known injection technique. A further method is known as extrusion moulding. This consists of forcing the heated plastic material into a die by means of an extrusion machine. The die is heated and when filled is cooled down, the cooling process starting at the point remote from the feed nozzle and progressing gradually to the feed whilst pressure is maintained. Quite large mouldings can be very successfully made by this method.

Most thermoplastics may be extruded in rod, tube or section form. They can also be extruded on to cables to form the dielectric. Call-endered sheet and film is another process commonly used for some thermoplastics.

Sheet thermoplastics such as cellulose acetate and methyl methacrylate become pliable when heated and can be readily shaped by pressing in moulds, stretching over formers, or blowing to shape either in air or in moulds. The material when heated has a soft rubbery consistency and single and double curvatures are made by quickly transferring the hot sheet to a former and clamping in position. It is then stretched over the former by pulling on the edges and clamping tightly until there is sufficient pressure to prevent the sheet leaving the contour of the mould. The clamps are left in position until the material has cooled.

The formers or moulds are often made from hard wood or bent plywood supported by a stout framework. They may be covered by a short pile fabric in order to protect the surface of the plastic material. Metal moulds are occasionly used when the number of pieces to be produced justifies the expemse of producing a perfectly smooth and highly polished surface. Metal moulds should be heated to about 40°C in order to prevent chilling the sheet too rapidly.

Generally speaking, articles made from plastic materials are considered as being finished, requiring only a flashing and sometimes a polishing operation. In some cases, however, it is necessary to perform subsequent machining operations. Wherever possible machining operations on moulded parts should be avoided as in the long run they are not economical and present machining difficulties. In the case of parts produced from resin bonded laminated materials, machining is necessary and can be performed provided that precautions are taken with tools used and the speeds and feeds applied.

Many of the thermoplastic materials machine very easily and no special tooling is required but the thermosetting plastics are very abrasive and call for special care. Generally, sharp tools are the

first essential in order to prevent burning and to obtain a good finish. Adequate arrangements to keep the cutting edge free from swarf will help this and will prevent clogging of tools such as twist drills and taps. Tipped tools give good results but diamond tools are better especially where a high finish is required.

Design Considerations.

In the past a great deal of harm has been done to the Plastics Industry due to designers copying metal parts when it has been decided to replace an existing metal part with a plastic part. This was probably due to insufficient data being available, but at the present time, this reason can hardly apply. It cannot be too strongly stressed that if plastics are to be used to maximum advantage, it is essential to treat plastics on their own merits, to study their properties and means of fabricating them.

Sharp corners and sudden changes of section should be avoided, particularly on moulded articles. It has already been noted that the strength of plastics is considerably less than the strength of metals. The designer will, therefore, have to consider increased thicknesses and provision of stiffening webs in order to achieve the desired results. Close co-operation between the plastics manufacturer, the moulder and the designer will usually result in the most satisfactory material being worked in the most economical manner in order to achieve the maximum advantage.

Applications

At first, plastics were used as substitute materials, replacing wood, ceramics, and metals. This was due to a large number of desirable properties—ease of colouring, resistance to chemical attack, low electrical and thermal conductivity, and ease of manufacture. Latterly, plastics have been used to supplement supplies of metals and light alloys, but there is a growing demand for plastics, not as substitites, but because they are specially adapted to particular applications, sometimes even because they are the only possible material for a novel use. Many new applications have already been published during this war, and when it is over, it will be possible to mention further applications where light-weight, electrical and chemical properties and ease of manufacture have pointed to one plastic or another as the only possible solution.

The application of plastics to electrical work, instrument cases, and the like, are familiar to all engineers. Silent gears and water lubricated bearings are also familiar examples. Large gears are machined from blanks of laminated material, but small gears can now be made by the " tailored moulding " process. Small gears for instruments made from thin sheet laminated material can be satisfactorily produced by blanking from the strip.

Bearings made from laminated materials have successfully replaced rolling mill beaings made from bronze. These plastic bearings have a longer life and result in reduced powder consumption In addition, they operate with only water as a lubricant, although it is often usual to employ a grease-water combination.

Experiments have been made in America with nylon bearings and promising results have been obtained.

Improved wood has many engineering applications, among the most interesting being airscrew blades. These are machined from boards which have a variable density, that at the tip of the blade being 60 lbs/cu.ft. and at the root 82 lbs/cu.ft. The change of density is made possible by a two-way consolidation. The board is first pressed to a density of 60 throughout. With pressure still applied to top and bottom faces, pressure is applied from the sides. This corrugates the veneers and gives the required density of 82 at the root. The change in density is spread over several inches and progresses without blemish throughout the length of change.

The aircraft industry uses plastics for many applications. Among them are petrol tanks and hose, cable covering and conduit for housing the cables, numerous mouldings for instrument covers, switches, controls, pulleys, D.F. loop housing, aerial mast and such parts. Pilots seats are made by the " tailored moulding " technique from impregnated paper. Perhaps the best application of all is the Mosquito aircraft which is built from shaped laminated wood using a synthetic glue.

The transparent plastics, cellulose acetate and plasticised polymethyl methacrylate are used for glazing gun turrets, bomb aimers compartments, astro-domes, pressure cabins, and generally all glazing required in an aircraft. The good mechanical and optical properties combined with a low specific gravity make these plastics ideal for this particular application.

The ship building industry uses plastics in an increasing number of applications. Numerous lighting and decorative fittings are in use. Small craft have been constructed from laminated materials, and improved wood is used for many and varied purposes.

As has already been stated, electrical engineers were among the first to recognise the possibilities of plastic materials and the applications in this industry are many and varied. It is probably true to say that without plastics the electrical engineering industry would have been greatly hampered in its own development.

Automobile engineers have found use for plastic materials for window frames, instrument panels, control knobs, steering wheels, and many other applications. Caravans and trailers lend themselves to the use of plastics and can be almost completely constructed from them, frame members being made from improved wood, covered by a shaped plywood skin,

Chemical engineers have found applications for plastic materials to line pipes and vessels in order to protect plant from chemical action.

Engineers generally and perhaps the aircraft constructors particularly have used improved wood for many applications, the most interesting perhaps being for press tool and forming jigs. Assembly jigs and reference gauges is another use to which this material has been put. One of the features of these tools is their strength/weight ratio, the specific gravity of the wood being in the order of 1.4. This means that quite large tools are comparatively light in weight, thus making for easy handling and expediting setting-up operations.

This brief survey of applications of plastic materials is by no means complete, but serves to indicate the versatility of the many materials available and indicates some possible further developments.

Potentialities of Plastics

It is safe to predict that in the normal course of development of existing plastics, uses in all branches of engineering will increase. Wherever a job can be done in wood, it is possible that a better and more colourful job can be done by a combination of wood and some other material. Already many new ideas are mooted. The decision will eventually turn on cost and availability. If a particular plastic is expensive, it is due to a combination of factors—a complicated synthesis, low yields, and, more particularly, low output and expensive finishing operations. If the engineer can devise cheap methods of converting the plastic into the finished article in large quantities, it can be left to the plastic manufacturers to improve on methods of synthesis. Fortunately, there is a great variety of potential plastics from which to chose the cheapest.

Another safe prediction is that the strongest and most stable of the transparent sheet plastics will find wider use as light structural materials. Glass is used to some extent in building construction, but the transparent thermoplastics have the advantage of being much less brittle, lighter, easier to shape, and may be sawn, drilled and machined.

Extrusion of insulating plastics round wires and cables and as sleeving is also bound to supplement methods of insulation.

The chemical engineer will also use extruded plastics, such as more rigid compositions based on polyvinyl chloride, to solve corrosion problems which previously demanded special alloys. Simple welding and jointing methods will be employed in manipulating extruded tubes and sheets, and there will be a general trend towards fabricating large articles by adaptations of metal working techniques.

There is a further extension of the use of plastics which does not involve any great improvement in the plastics themselves. That is the combinations of plastics and other materials. The general usefulness of combinations of phenol formaldehyde and cellulose has been noted already. Much greater use could be made of composite metal plastics structures. Developments are already proceeding with the combinations of glass fibre with plastics.

There is much to learn about the properties of plastics as engineering materials and about the best way to design in order to make use of their properties. Far sighted engineers will start building up that knowledge in order to extend the use of the oldest and the newest plastics and in anticipation of the improved plastics to come.

In conclusion, I should like to acknowledge the assistance given by my colleagues in the preparation of this paper and to Imperial Chemical Industries Limited for permission to publish it. I must also thank Mr Chapman of Aeroplastics and Mr. Basset of Ashdowns Limited for loaning moulded articles for exhibition.

Research Department: Production Engineering Abstracts

(Prepared by the Research Department.)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

SMALL TOOLS.

Mounting Solid Cement-Carbide Cutting Blades Mechanically, by W. L. Kennicott. (*Mechanical Engineering (U.S.A.), April, 1945, Vol. 67, No. 4, p. 241, 16 figs.*).

A recent development in the use of cemented-carbide cutting tools has been the adoption of solid carbide blades, mechanically held in standard or special tool holders. There are several advantages, including: more regrinds, greater strength, elimination of thermal strains, and simpler grinding. The design development of mechanically held carbide-tips or cutters in single-point tools is described and illustrated. The current design has a small clamp on an angular ledge at the back edge of the carbide. The shank is heat treated to provide a durable flat seat, and the clamp merely holds the carbide against this seat, the shoulder alongside, and the advancing screw at the back end. Heavy roughing work on large parts is a relatively new field for carbides, opened up through the use of mechanically held carbide cutting blades. While the same jobs can theoretically be done with conventional brazed tools by stepping up the speed and cutting down on feed, the machines on which such jobs are turned will not usually turn fast enough. Even on specially built machines, large irregular castings or forgings cannot be rotated rapidly due to out of balance. Centres become a problem on such large work, and they can handle the large weights more easily with lower revolutions. Use of heavier feed eliminates the need for chip breakers, increasing the rate of removal for a given available horse power. The cutting speeds and feeds used with these tools on heavy work are shown. Use of solid carbide blades in double-negative-rake milling has resulted in particularly outstanding results. This is not due to the fact that a solid carbide cutting blade, mounted in a milling cutter, is any better than one mounted in a single-point tool, but rather that a brazed multiple-point tool has more strains than a brazed single-point tool.

Turning of Commutators with Diamond Tools. (*Industrial Diamond Review, April, 1945, Vol. 5, No. 53, p. 76, 4 figs.*).

Big commutators are mostly turned on site and the tool arrangement is described. Data for rates of feed and cutting speeds are given. It is of importance that during the turning all parts of the commutator are well protected against the swarf and a device has been invented for blowing or sucking away the swarf as soon as it is generated. Small commutators are usually turned on very high speed precision lathes which must run absolutely free from vibration. They are turned between centres or run on their bearing

journals. Up to 20,000 commutators for small motors of household apparatus can be turned with a single setting of the diamond tool, before re-sharpening of the diamond becomes necessary.

(*Communicated by Industrial Diamond Review*).

Tipped High-Speed Steel Widely Used, Survey Shows, by Frank J. Oliver. (*The Iron Age, 18th January, 1945*).

When the supply of alloying elements for high speed steel became critical about two years ago, many methods of using this cutting tool material in tip rather than solid form were publicised. To discover to what extent these practices have actually been used in industry, a survey was conducted, and this report summarises the results of it.

(*Communicated by Machine Shop Magazine*).

Milling Cutters and How to Use Them, by M. Martelloti. (*The Machinist, 14th April, 1945, Vol. 89, No. 1, p. 24, 8 figs.*).

The hand of the helix and the hand of the cut have a direct effect on design of milling fixtures. The forces on the cutter and workpiece are analysed for a number of cases, and the effects of these forces are indicated.

SURFACE, SURFACE TREATMENT.

Symposium on Surface Finish. (*The Engineer, 16th 23rd, 30th March, 1945, Vol. CLXXIX, Nos. 4653, 4654, 4655, pp. 209, 230, 250*).

A whole-day conference on problems of surface finish, arranged by the Institution of Mechanical Engineers, was held on the 9th March. A symposium of papers was presented, arranged in five groups :

Group I—Physical Aspects.

The Structure of Sliding Surfaces, by Professor G. I. Finch.

Sliding surfaces are meant to be kept apart by the lubricant, and if this were achieved in practice, wear, apart from corrosion, would hardly occur. The trend in mechanical engineering today, however, is to take such full and swift advantage of any advance in surface finish or lubrication that attention has become focussed mainly on boundary conditions of lubrication and particularly on their breakdown and its consequences. With the tendency towards increased loading it is unlikely that improvements in surface finish and lubrication will ever quite eliminate breakdown. Thus breakdown has to be accepted and we must understand the nature of the resulting surface changes, and take steps to suppress harmful breakdown effects and promote those conducive to low friction and wear. Electron diffraction has thrown fresh light on these problems, and this paper describes the findings. Attention is particularly drawn to the importance of operations on a surface prior to final finishing. If the pre-history process has broken up the crystal structure and thus hardened and toughened the material to a considerable depth below the surface, excessive wear can occur. Excessive scoring and heavy wear may be the result even though, when judged by profilometry or the microscope, the original surface finish appeared unexceptionable.

A Short Review of Surface Finish in Relation to Friction and Lubrication, by D. Clayton, D.Sc.

This paper first studies published knowledge upon dry and boundary lubrication as relating to surface finish. It is important to note the influence

of geometrical truth in mixed lubrication ; untrue surfaces, however smooth, allow contact to occur relatively easily, and the effect can be much greater than that of roughness. In the case of internal combustion engine cylinders finish is important in regard to running-in, wear and scuffing. It is a point for discussion whether the roughness should be provided for the rings and the cylinder left smooth, or whether the cylinder should be roughened alone or as well as the rings. " Phosphating " has several interesting features in connection with surface finish. The soft, easily worn surface promotes quick running-in ; it reduces the deleterious consequences of geometrical irregularities on load-carrying capacity—the author has used it to remedy poor machining of slides, and it might find ultimate field in avoiding the expenses of high finish. Under severe rubbing conditions the load-carrying capacity of surfaces is increased as though by a chemically active lubricant ; thus the scuffing of piston rings and gears is deferred or prevented. There is no doubt as to the need for much more systematic work to establish firm relations between surface finish and lubrication phenomena, some of it depends on progress in other fields, such as, for example, the specifying of the roughness of surfaces.

Group II—Methods of Measurement and Representation of Surface Roughness.

Some Principles and Methods of Surface Measurement, by R. E. Reason.

It seems probable that the functional significance of imperfections of given height and shape will differ greatly according to their wave-length. Thus an excellent " smooth " surface can be turned into quite an indifferent " rough " one simply by changing the wave-length of the irregularities and without changing their height at all. This point is vital, for on it hinges the question of what an instrument for measuring surface finish ought to measure, It is usual, and for average measurements essential, to describe surface finish, not with respect to a fundamental reference surface, but with respect to one determined relatively to the irregularities themselves. The most practical reference line appears to be the centre line, defined as a line with respect to which the r.m.s. value is a minimum. Instruments measuring the height of a part only of all the possible range of wavelengths may be called selective. While the simple centre-line system of measurement may not be ideal, it has the advantage that when the selectivity is specified, it becomes a definite measure which can be made independently of any kind of personal judgment. Standardisation of instruments in respect of selectivity is obviously required, but so little is known about the functional significance of wavelength that at least for the present it is necessary to assume that different degrees of selectivity must be catered for. If all commercial instruments were constructed with cut-offs at one or other of standard values, as might seem best to maker and user, there would be built up, in course of time, an immense amount of coherent data amenable to statistical analysis, on the basis of which sound workshop standards of different classes of work could be laid down. The need for industry is for simple workshop instruments giving sensible measures of surface quality. Their provision is impeded mainly by lack of sound experimental data on what really needs to be measured, and on how accurately measurements should be made. When all the factors to be taken into account are considered—factors concerning the physical structure and behaviour of the surfaces, geometrical factors concerning the effect of different profiles and wavelengths, and the effect of all these in relation to stress and lubrication—it becomes clear that a great deal of work will be required before general principles can be firmly established.

Measurement of Surface Waviness, by C. Timms.

The inspection of surface finish has hitherto been mainly confined to the measurement of the fine surface texture caused by the cutting action of the tool. In addition to the measurement of the fine surface texture, however, the inspection of the finish may be complicated by the presence of surface waviness having a pitch greater than the traverse feed of the machine. This waviness is referred to as " macro-roughness " and is generally associated with varying conditions of the machine traverse and vibration. In certain cases the amplitude of the macro-roughness may be of greater importance to the functioning of the component than the magnitude of the fine surface texture (micro-roughness). In order to measure the amplitude and to study the periodic nature of the undulations it is necessary to traverse across several cycles of the wave. With existing types of surface-recording instrument, this is not in general possible, due mainly to the restricted traverse length, which does not exceed about $\frac{1}{4}$ in. In addition, these instruments normally generate their own datum line by means of a radius skid which contacts the surface under test. With the longer pitched waves, however, the skid may tend to follow the shape of the surface unevenness and thus falsefy the resulting record. The paper describes a portable instrument of simple construction designed at the National Physical Laboratory for the measurement of the grosser surface irregularities.

Group III—Considerations of Rational Specification and Requirement in Surface Finish.

Drawing Office Specification, by H. J. Griggs.

The standards proposed by the B.S.I. are admirably suited to replace existing symbols and to supply a much more accurate definition of the designers' intention and the functional requirement of the part to be manufactured, but the recommendation to specify the method of finish by a letter within the triangle supplementing the grade of finish outside the triangle is of questionable value, since modern production planning relieves the drawing-office of the responsibility of defining methods of machining, so long as the finished size and grade of surface finish is specified. The grades of finish chosen should allow the highest average figure permissible, and thus avoid any need for stating a tolerance. The idea of specifying surface finish is now generally accepted, and it is not desirable that the interpretation of the idea should be expressed by symbols as international as those used in music, physical science, or chemistry. Opinions may differ upon the exact significance of the average number stated in the grades chosen by the B.S.I. but this simple grading system is immediately available, and experience and practice with it will soon ensure uniformity of results.

Rational Specification of Surface Finish, by W. A. Tuplin, D.Sc.

Whilst a perfectly smooth surface is a practical impossibility, it may nevertheless be regarded as an ideal at which to aim. The roughness of a surface may be measured by the amount of work that must be done on it to bring it within some arbitrary distance of theoretical perfection. A system of surface finish assessment on a similar principle has been suggested by Abbott and Firestone, but it does not appear to be in general use. The profile of the surface in one particular plane is not necessarily a close indication of the general character of the surface, and the profile in a plane perpendicular to that of the first profile may be of a different nature. The general problem of determining a " roughness figure " from pen records of a surface is more difficult than may at first appear, and a rational method of solving it may

involve more arithmetical work than is required on the basis of established methods. The remarks refer particularly to conditions where " area contact " is desired, as, for example, on such surfaces as cylinder bores. In other cases, e.g., gear teeth, line contact is all that can be expected, and this condition has an influence on selection of the method of testing surface finish.

Requirements in Surface Finish, by D. McConnell.

Generally speaking, the requirements of surface finish are concerned with the reduction of wear, and final decisions must largely rest on the observed results of work with known surface finishes. Production departments must then devise means of satisfying these requirements within practical limits. At present, in the absence of any criterion, requirements can only be based on existing work. From the engineers' point of view it is essential to give a specification which can be put on a drawing, and which is universally understood. Surface finish must not be confused with surface flatness. The latter could be taken as a " macro-analysis," and is already defined and employed in engineering. Surface finish relates purely to the " texture " of the surface. At present there is no definite relation between different systems of surface measuring, and for the future application of these methods this point should be insisted upon early in the history of the subject. Broadly, one must appreciate that if it becomes common practice to specify surface finishes against particular surfaces on a drawing, then the part must be capable of inspection in this particular.

Group IV—Production Methods and Results of Modern Practice.

Surface Finish on Production Methods, by W. E. R. Clay.

Grinding has one inseparable disadvantage in the fact that owing to the high heat generation at the contact line between wheel and work the torn and fragmented surface of " fuzz " metal is plasticised into an extremely thin layer of decarburised material, the removal of which necessitates a " running-in " process. " Chatter " or circular lobing occurs frequently in the grinding process, as also does longitudinal waviness, and both these defects are brought about by the many variables which arise in the condition of the wheel and the machine. Waviness is widely variable, depending on the class of work. The resulting degrees of accuracy from the honing process are measured in two or three hundred-thousandths of an inch on small bores around 0.250 in. to 0.750 in. diameter and one or two ten-thousandths of an inch for larger bores. External diameters are honed to within two or three hundred-thousandths of an inch for size and parallelism. Where necessary, flat surfaces can be honed within a parallelism of 0.00005 in. Super-finishing is the light application of a lubricated abrasive stone or stones to the work surface, reciprocated with a high-speed short-stroke action, plus a reversing traverse of the stone holder, coupled with work rotation. The three motions cause a scrubbing action on the surface, removing only the " fuzz " metal. As soon as this surface roughness is removed the abrasive action ceases. The usual amount of metal removed is measurable only in hundred-thousandths of an inch and for normal work no allowance is made for the operation. Running-in time can in some cases be eliminated. The operation is not strictly a dimensionally corrective one for parallelism or circularity, although fine chatter marks in a circular direction can be removed. Qualities of finish and allowances for the various processes are given.

Results of Modern Practice, by F. Nourse.

Before 1939, surface finishes were judged visually and in comparison with reference pieces and models. In the main the type of surface finishes were maintained by the consistent use of methods which had been developed and established to produce the type of finish which experience had shown to be satisfactory in performance. To a large extent this is still the case, but since satisfactory surface measuring instruments have become available it is possible to assess more critically the requirements of particular surfaces, especially where the duty has become heavier, and to determine the control more closely the required method of production. Geometric faults can to some extent be dealt with dimensionally or by marking, but some of the more subtle faults need new instruments to assess them. The application of surface finish measuring to production may be summed up as follows: (1) To determine and maintain the standard of finish within the range of variation permissible with established methods of production which have proved to be satisfactory in functioning. (2) To ensure that any change of method, machine type, or tooling produces results within the desired range. (3) To improve or otherwise modify existing standards where this is shown by experience to be advantageous to functioning, and to approve any necessary modification of methods of production. (4) To lower existing standards where this is an advantage to production and not detrimental to functioning.

Group V—Effect of Surface Finish on Performance.

Continuity in the Production of Specified Surface Finish, by E. Swain.

Present practice leaves some scope in the power unit for improvement by the application of surface refinement to such items as crankshafts, valves, and their operating mechanism. In cast iron cylinder bores a smooth bore of 8 micro-inches takes a fair amount of coaxing to complete its bench test of seventeen hours without scuffing of the bores, pistons, and rings, where bores with a roughness of 30 to 40 micro-inches give no such trouble. It takes seventeen hours' running to reduce a surface finish of 35 to 40 micro-inches to 5 to 7 micro inches, whereas an initial surface finish of 8 micro-inches is reduced to 2 or 3 micro-inches in five hours or less, with no further reduction for twenty-five hours, but there is the undesirable tendency for seizure and scuffing. Test figures and curves are given for rate of surface improvement, initial friction, and friction after five hours' running, with 35 and 8 micro-inch bores. The development of super-finishing is not accidental. if it is realised that the gap between grinding and lapping is in effect fairly wide. High standards of finishing, using either method, are comparatively slow, with limited applications; super-finishing fills the gap, eliminates lapping, and the finer grinding, and gives a higher rate of production, coupled with ease of repetition for a specified surface finish with close limits.

Effect on Fatigue Strength, by W. Ker Wilson, D.Sc. (Eng.).

In aero-engines careful attention to surface finish is essential before full benefit can be obtained from high strength alloy steels. Typical service failures of aero-engine components show that a single surface blemish may be a potential nucleus for fatigue or impact failure, especially if, in addition, the form of the part is poor. The influence of cutting, grinding, and polishing operations on fatigue strength may be favourable or unfavourable according to the fineness of the finish and the nature of the residual stresses. Residual tensile stresses are harmful, whereas, within proper limits, residual compression stresses may be beneficial. Since a fine finishing process, such as lapping

or super-finishing, reduces wear and fretting tendencies, the actual gain in strength from the process may be considerably greater than is indicated by the results of simple fatigue tests. Examples of the influence of surface finish on bending fatigue strength of steel are given. Strength and wear resistance can be increased through surface hardening by heat treatments, such as case-hardening, flame-hardening, and nitriding, or by mechanical treatments, such as cold rolling and shot blasting. Surface coatings may be beneficial in improving resistance to fretting, corrosion, and heat. The paper studies the effects of these processes in detail.

Locomotive Practice, by F. C. Johansen.

Robust machines, designed for reliability under exacting service, and to withstand a certain amount of ill-usage, suffer working distortions demanding clearances between adjacent surfaces such that the state of finish may be unimportant within wide limits, while damage attributable to abrasion debris is slight. Thus, the cost, time, and difficulty of super-finishing large surfaces may be disproportionate to the prospective benefits. The influence of the conditions of service maintenance and long life of a locomotive has the consequence that the only surfaces to which exceptionally fine finish is imparted are on parts which may give immediate trouble and never be self-rectifying without such attention. Thus, journals of coupled wheel axles have shown, over a number of years, that progressive improvement of surface finish diminishes the occurrence of over-heated bearings, especially in the early stages of use. The present tendency, therefore, is for all engine and tender journals to be fine-turned, fine-ground, and finally lapped. With few exceptions most contact surfaces on a locomotive receive no more than a fine carbide tool turned, or ground finish. Cylinder bores and piston rings, for example, are only turned, while crosshead slide bars are given a moderately fine ground finish. The effect of super-finish on the behaviour of interference fits is a prospective subject for research. In this connection, an aspect of performance that can be markedly affected by surface finish is the endurance of a component subject to fatigue stress.

(Reports on the discussions following the above papers are also given. Similar abstracts appeared in : *Engineering*, for March 16, 23, 30, April 6 and 13, and *Machinery*, for March 15, 22 and 29).

The Pickling of Steels, by Edward W. Mulcahy. (*Sheet Metal Industries, April, 1945, Vol. 21, No. 216, p. 620, 7 figs.*).

Part VI. Pumping acid solutions.

TRANSPORT.

Easy Internal Transport. (*Production and Engineering Bulletin, April, 1945, Vol. 4, No. 28, p. 115, 21 figs.*).

Trucks and hand-drawn stackers designed for numerous purposes to aid the efficient handling of work, tools and plant.

WELDING.

Fabrication Costs of Boilers, Tanks, and Pressure Vessels, as Affected by Width of Plates, by W. G. Theisinger. (*Mechanical Engineering (U.S.A.), April, 1945, Vol. 67, No. 4, p. 247, figs. 12*).

A detailed analysis of the cost of fabricating welded vessels, with different widths of plate.

Application of Arc Welding to Machine Tool Production. (*Machinery, 26th April, 1945, Vol. 66, No. 1698, p. 451, 7 figs.*).

There are a number of reasons why it is not practicable to weld everything ; among these is the poor vibration-absorbing characteristics of steel, resulting in tool chatter and poor finish. Another point to be considered is that cast iron has good bearing qualities, wheras steel will gall in some instances unless a properly heat treated alloy steel is used. A further disadvantage with a welded design is that steel is more difficult to machine than cast iron. On the other hand, there are many advantages. First, steel is more than twice as stiff as cast iron and it is possible to reduce the weight of a given section by almost 60%. The use of fabricated steel will often provide more room in the machine itself than could be obtained with other methods of construction. Another important item is that of cost. In some cases, the use of rolled steel actually reduces the amount of machining required on a part. Combining several parts, that are usually bolted together, into a welded structure eliminates the necessity for drilling, tapping, and milling the faces to be bolted. The use of fabricated steel in new designs eliminates pattern and pattern-storage costs. Further, since the steel parts are lighter in weight than the corresponding cast-iron parts, the steel parts are easier to handle in the shop. A plant must be properly equipped to do production welding in order that the savings outlined may be made, and a definite personnel development programme is helpful in a welding department. The latter part of the article deals with the manufacture of typical components, and describes jigs and fixtures used in welding, type of material selected for welded work, and applications of welding.

Automatic Arc Welding. (*Machinery, 5th April, 1945, Vol. 66, No. 1695, p. 361, 7 figs.*).

Part I. In general, increased speed of arc travel is not the factor of primary importance. The main factors in the economy of machine welding are the increased duty factor and the uniform quality which can be achieved. Types of automatic welding heads may be classified as follows : 1. Metal-arc welding with bare and lightly coated electrodes. 2. Shielded-arc welding with coiled electrodes. 3. Shielded-arc welding with short lengths of electrodes. 4. Carbon-arc welding. 5. Inert-gas shielded arc welding, with or without the addition of filler. 6. Atomic-hydrogen arc welding. In the units described, electronic-tube control panels are employed to regulate the speed and direction of rotation of the electrode driving motor. In order to get the maximum benefit from machine welding with the automatic welding heads described, three factors are essential : First, there must be a sufficient quantity or volume of production involved to pay for the fixed charges on the automatic welding heads and the mechanical fixtures and handling devices that must be used with them. Secondly, uniformity in the product is essential to economical machine welding. Thirdly, machine welding should be mechanized in so far as possible. Practical factors in machine and fixture design, and operating technique are discussed in detail.

The Application of Refrigeration to the Cooling of Spot Welding Electrodes, by W. S. Simmie. (*Sheet Metal Industries, April, 1945, Vol. 21, No. 216, p. 687, 4 figs.*).

Before describing his own tests the author briefly indicates the conclusions from work done in the U.S. The present work was carried out on an electromagnetic stored energy resistance welding machine, and a refrigerator was used to feed a 50% alcohol—50% water mixture to the welding electrode.

The tests included the spot welding of 20 gauge (.036 in.) 5 L3 Duralumin and Al clad DTD 390. Comparative tests were obtained for two electrode materials and three electrode tip shapes. The test pieces were degreased and chemically cleaned before welding. The electrodes were carefully machined to size and for each test a new pair of electrodes were used. This investigation clearly indicated that the uncoated sheet 5 L3 is less troublesome to weld than the Al clad sheet. The refrigerated coolant was found to reduce the amount of wear on the electrode tips and the results indicate that the weld strength is maintained over a long test run, but it was difficult to detect any marked increase in the number of welds which could be made before sticking occurred. It may be that the controlling factor is not the initial temperature of the tip but the proximity of the cooling liquid to it.

Welded Airscrew Hubs. (*Aircraft Production, May, 1945, Vol. VII, No. 79, p. 210, 21 figs.*).

This article, prepared by the chief metallurgist of Rotol, Limited, is a survey of the comparatively new flash-butt welding process of producing hubs for airscrews. It shows that considerable material and time economies have been effected by the new technique.

INSTITUTION NOTES

June, 1945

1945.

July Meetings.

Wolverhampton Graduate Section. Special Meeting for Graduate and Students only (No Visitors). "Brains Trust." Full details to be announced later.

7th Shrewsbury Sub-Section. A lecture will be given by R. C. Fenton, Esq., on "Negative Rake Cutting," at the Technical College, Shrewsbury, at 3-0 p.m.

13th Manchester Graduate Section. A lecture will be given by D. H. Bramley, Esq., on "Production Planning" at the College of Technology, Manchester, at 7-15 p.m.

17th Wolverhampton Section. A lecture will be given by W. Swift, Esq., on "Negative Rake Milling," at the Wolverhampton and Staffordshire Technical College, Wolverhampton, at 6-30 p.m.

Meeting with Section Secretaries.

On Wednesday, 30th May, 1945, a Conference between Section Presidents and Secretaries and representatives of the Technical and Publications Committee was held at the Queen's Hotel, Birmingham. Mr. Alastair McLeod (Chairman, Technical and Publications Committee) presiding.

The topics discussed included the introduction of symposia into the general programme of sections, methods of submission of papers, the form of the Journal, the pooling of lecturers, and the desirability of films as an aid to section programmes. Various points of office procedure were discussed with the Director-General Secretary, Major C. B. Thorne, M.C., especially in regard to mailing, local printing of tickets, etc.

Personal.

W. A. HARRIS, ESQ., M.I.P.E., has been appointed Works Manager of Cornercroft (Northern) Ltd., and of Cornercroft Ltd. (No. 2. Factory), also Director of Cornercroft (Plastics) Ltd.

Sir George Edwin Bailey, C.B.E., M.Sc., M.I.P.E., M.I.E.E., M.I.Mech.E., who was made chairman of the Metropolitan-Vickers Electrical Co., Ltd., in March, 1944, has been appointed managing director of Associated Electrical Industries, Ltd. Of the many public offices held by Sir George, the first in importance is that of president of the Engineering and Allied Employers' National Federation, which office he held from 1940 to 1943. He became trustee to the Federation in 1943, and was also President of the Institution of Production Engineers from 1939 to 1942. Other offices Sir George Bailey has filled include the presidency of the Manchester District Engineering Employers' Association in 1926 and 1927, and member of the Beveridge Committee on Skilled Men in the Services, June, 1941. He also holds the following offices :—President of the Manchester Engineering Council, honorary treasurer of the Manchester District Engineering Employers' Association, and member of the North-Western Regional Board (Ministry of Production). He was conferred the degree of M.Sc. (Honoris Causa) by the Manchester University in July, 1942.

Obituary.

We deeply regret to record the death of C. B. Northey, Esq., M.I.P.E.

Important.

In order to get the Journal out to time, copy must reach the Head Office of the Institution by not later than 40 days prior to the date of issue, which will be the first of each month.

BOOKS RECEIVED

Diamond Tool Patents for Machining Metals and Non-Metallic Substances, by P. Grodzinski, A.M.I.Mech.E., and W. Jacobsohn, A.I.Mech.E. Price 1/6d. post free. The Diamond Trading Co., Ltd., E.C.1.

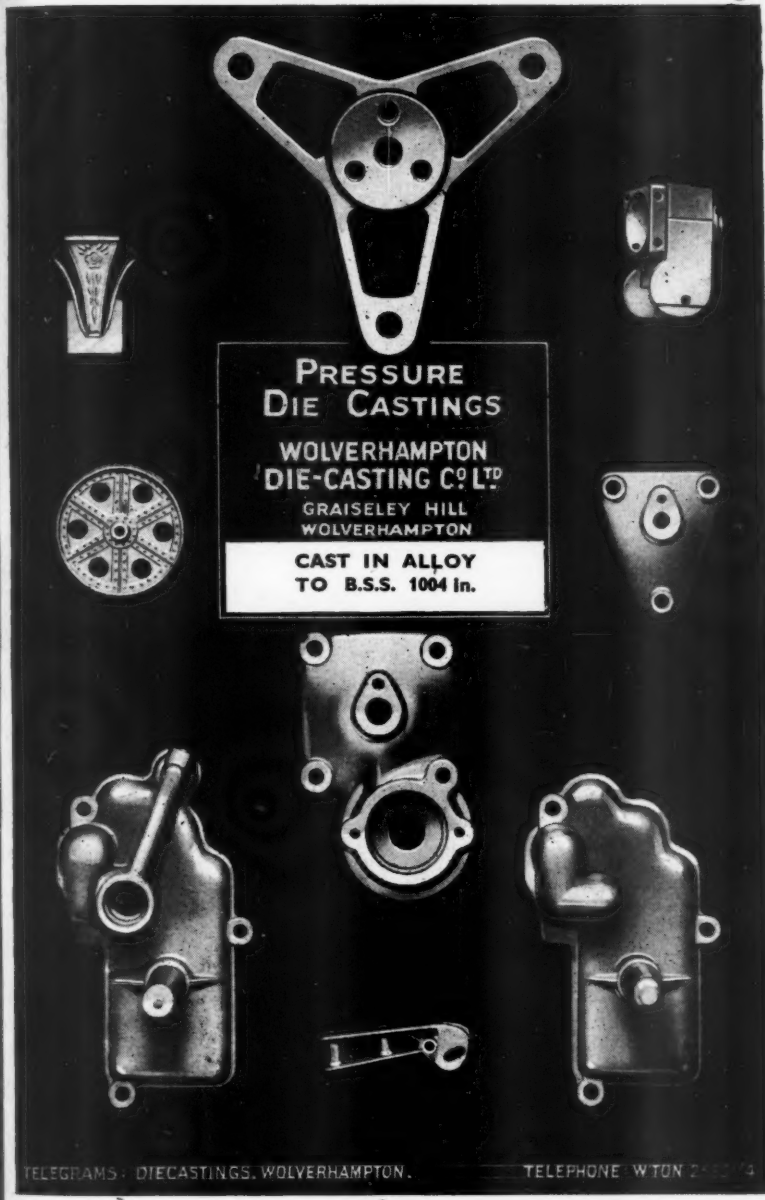
Testing Machine Tools, by Dr. Geo. Schlesinger. (New enlarged 4th Edition) Price 17/6d. Published by Machinery, Brighton.

INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A *and* B. *Advertisers' announcements only appear in one edition each month, advertisements in edition* A *alternating with those in edition* B *the following month. This Index gives the page number and edition in which the advertisements appear for the current month.*

	Page
Acheson, Ltd., E. G.	xxiv B
Alitools Ltd.	iii A
Arnott & Harrison, Ltd.	xx B
Asea Electric Limit d	xx A
Asquith, Wm. & Co.	xix A
Automatic Coil Winder & Electrical Equipment Co., Ltd., The	xxii B
Barber & Colman, Ltd.	xv B
Baty, J. E. & Co. Ltd.	xii B
Block & Anderson, Ltd.	iii B
Bratby & Hinchliffe, Ltd.	xxi A
British N.S.F. Co., Ltd.	xxvi B
Burton, Griffiths & Co. Ltd.	xxii A xviii B
Catmur Machine Tool Co. Ltd.	xv A
Churchill, Chas., & Co. Ltd.	xxv A
Cincinnati Milling Machines Ltd.	xvi A
Climax Rock Drill & Engineering Works, Ltd.	xxix A
Consolidated Pneumatic Tool Co. Ltd.	xvii B
Cooke, Troughton & Simms, Ltd.	vii A
Craven Bros. Ltd.	iv A
Daniels, T. H. & J., Ltd.	xxx B
Dawson Bros. Ltd.	xxiii A
Dean, Smith & Grace, Ltd.	xxvii B
Desoutter Bros. Ltd.	xxvii A
Drummond (Sales) Ltd.	ii B
Fenner, J. H. & Co., Ltd.	viii B
Firth, Thos. & Brown, John, Ltd.	x A
Foster Transformers & Switchgear Ltd.	xviii A
Gilman, F. (B.S.T.), Ltd.	viii A
Guylee, Frank & Son, Ltd.	xxxi B
Herbert, Alfred, Ltd.	v A xiii B
Higgs Motors, Ltd.	xiv B
Hiduminium Applications Ltd.	xxxi A
Holman Bros, Ltd.	xxxii B
Hughes-Gr en Engine ring Co. Ltd.	xxvi A
Imperial Smelting Corporation Ltd.	ix B
Jessop, William, & Sons, Ltd.	xii A
Keelavite Ltd.	vii B
Lang, J., & Sons, Ltd.	vi B
Leytonstone Jig & Tool Co. Ltd.	xxiiii B
Lund, John, Ltd.	xiv A
Macrome Ltd.	xxvi B
Midgley & Sutcliffe	x B
Midland Saw & Tool Co. Ltd., The	ix A
Moliart Engineering Co. Ltd.	xxiv A
Motor Gear & Engineering Co. Ltd.	xxviii A
Murray Colour Controls, Ltd.	xxviii A
Newall, A. P., & Co. Ltd.	xxxii A
Newall Engineering Co. Ltd.	xvi B
Newman Industries, Ltd.	xxvi A
Parkinson, J., & Son	iv B
Pryor, Edward, & Son, Ltd.	xxviii B
Reavell & Co. Ltd.	xiii A
Sanbra Group, The	xvii A
Sanderson Bros. & Newbould, Ltd.	xxx A
Selson Machine Tool Co. Ltd.	xxi B
Snow & Co. Ltd.	xxv B
Sparklets, Ltd.	xxiv B
Taylor, Taylor & Hobson, Ltd.	ii A
Timbrell & Wright Machine Tool & Engineering Co. Ltd.	xxix B
Urquhart, Lindsay & Robertson (Orchar) Ltd.	xi A
Voucher Ltd.	xxx A
Ward, H. W., & Co. Ltd.	v B
Ward, Thos. W., Ltd.	xxviii B
Wickman, A. C., Ltd.	vi A xi B
Wolverhampton Die Casting Co. Ltd.	xix B

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "The Journal" should not be taken as an indication that they are necessarily available for export.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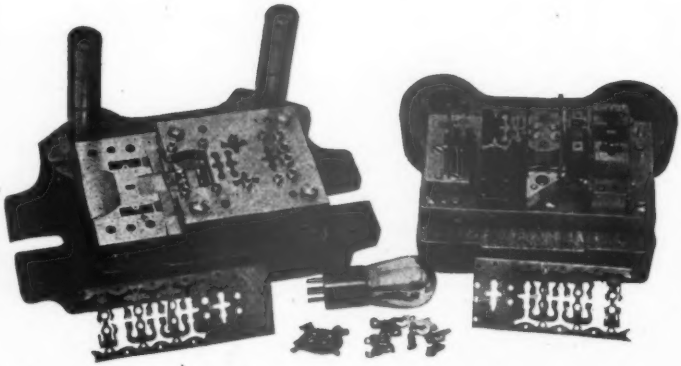

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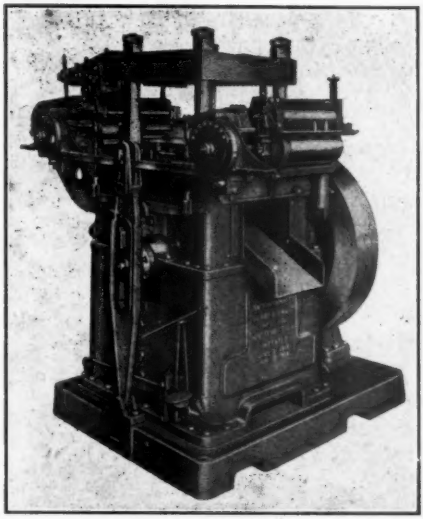

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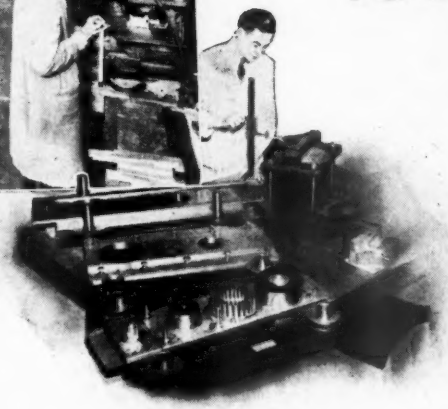

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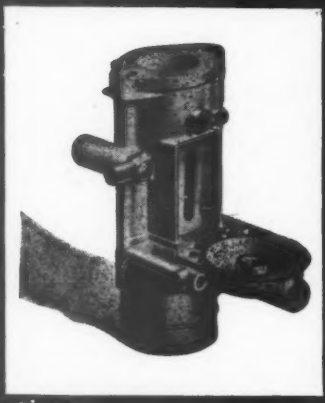

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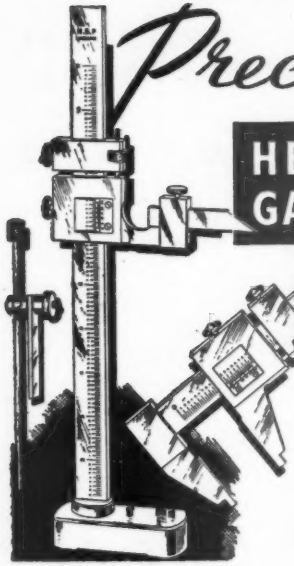

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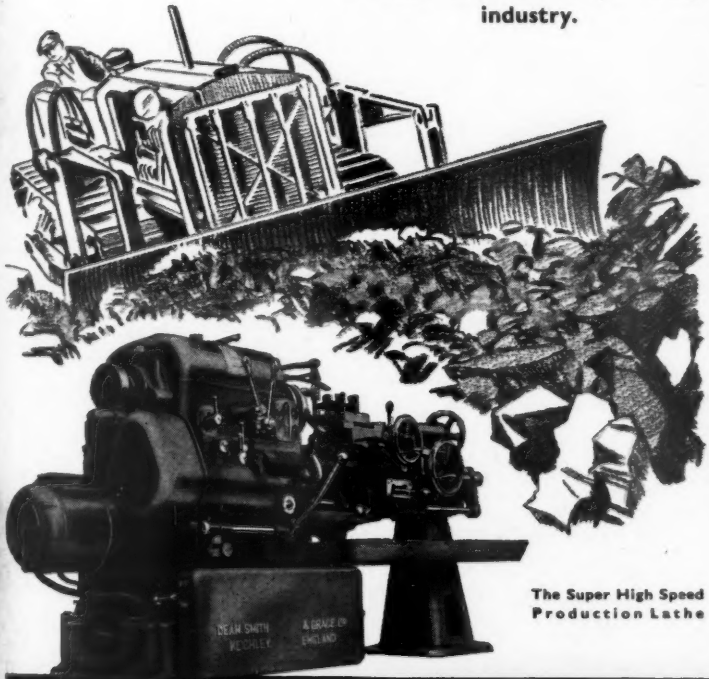

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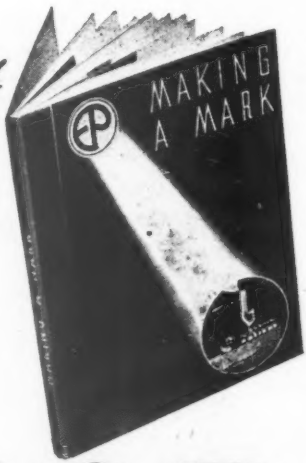

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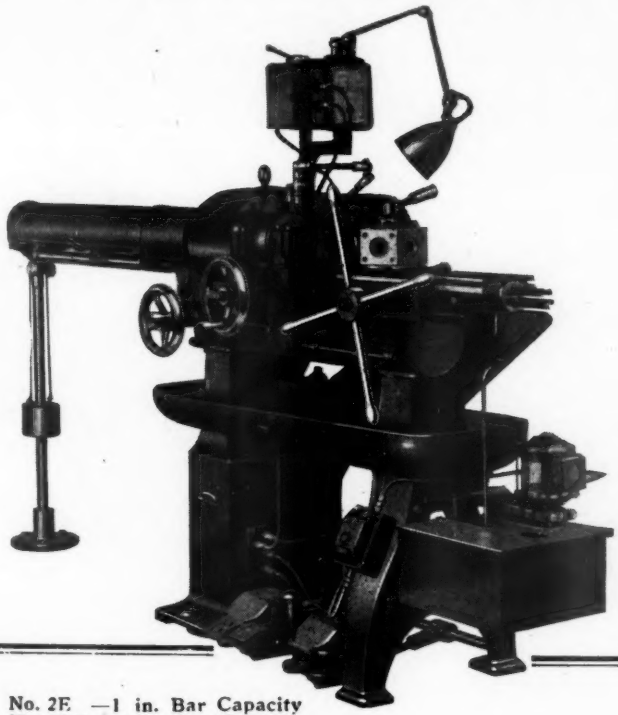

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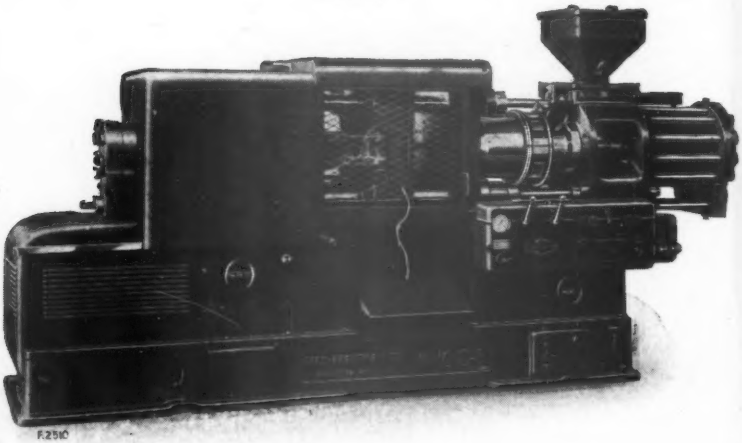

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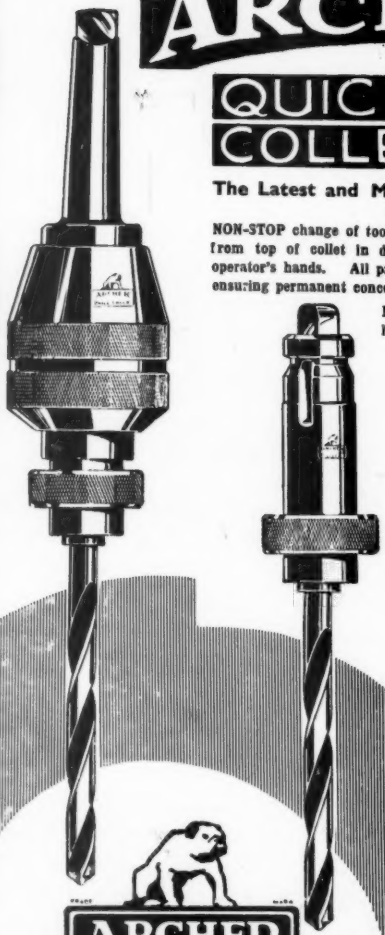

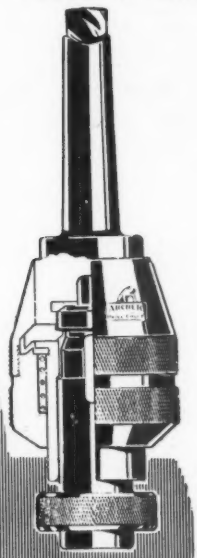

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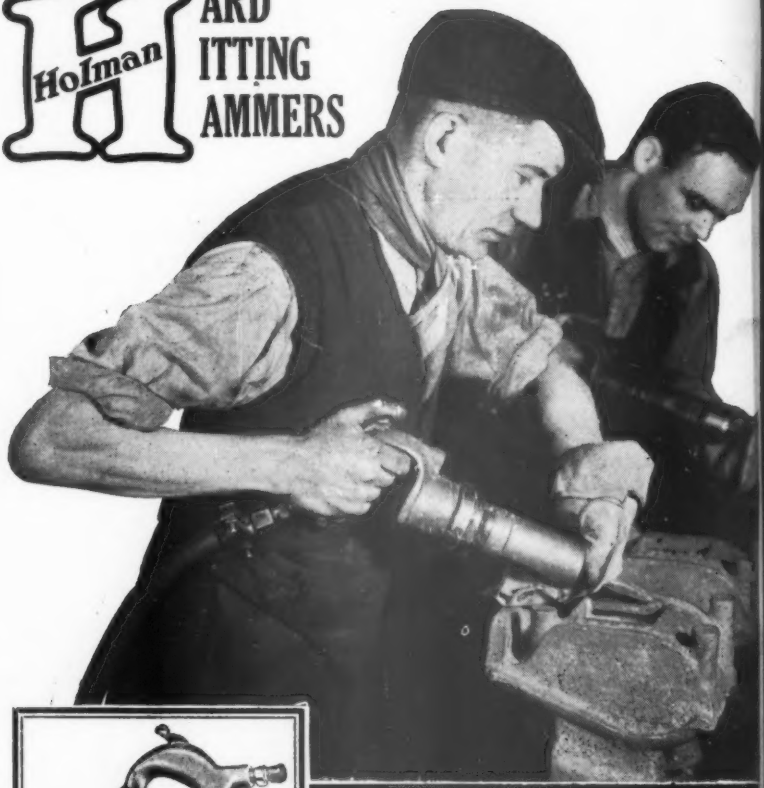

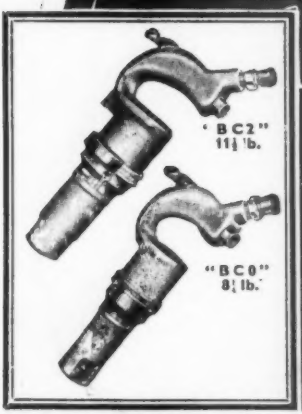

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(July, 1945, Vol. XXIV, No. 7, Ed. B)

Contents :

CAST IRON AND ITS RELATION TO MACHINE TOOLS

by P. A. Russell, B.Sc.

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